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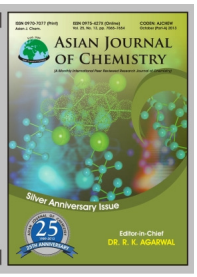

Study on Mineral Distribution of Peat Soil in Northeast China

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Peat soil is a special kind of humus soil that is abundant with organic matter, minerals and plant fibers. The plant fibers and organic matter are separated, respectively by using the rinsing method and the chemical methods. Dry soil samples are obtained to analyze the distribution of minerals using X-ray powder diffraction method with scanning electron microscopy and loss on ignition test. The main minerals found in the peat soil are clay minerals (illite, chlorite and kaolinite) and gravel soil minerals (quartz, plagioclase and mica). Illite is significantly reduced at 1.2 and 2.2 m depth. It is also partly transformed into kaolinite because of the impact of humic acid and internal porosity. Quartz and mica have similar distribution patterns that are significantly increased at 1.2 and 2.2 m depth on account of the tiny, but abundant, root flocculent structure. Plagioclase is distributed similar to that of illite.

Key Words: Peat soil, Mineral distribution, Chemical methods, Depths.

INTRODUCTION

Swamp peat soil is a special kind of humus soil with high void ratio, high water content, high permeability, high organic matter, low degree of decomposition and a formation age of less than 1 million years. This special kind of soil is formed by the plant remains in the surface swamp environment under oxidation and partial decomposition. Peat soil is widely distributed in the Changbai Mountains, Great Khingan Mountains, Lesser Khingan Mountains, Sanjiang Plain, most mountain areas in Xinjiang, Western Sichuan Zoige Plateau, Qinghai-Tibet Plateau, Yunnan plateau and in the Middle and Lower Reaches of the Yangtze River in China [1]. This soil consists of plant fibers (commonly from moss, sedge, reed and wood), humus and mineral matter[2]. As a result of the different depositional ages, the plant residual root and plant fibers, type and content of organic matter and minerals in the peat soil vary during the deposition process. These variations have significant impact on the study on the physical and the mechanical model of peat soil.

Therefore, conducting a study on the plant residues, organic matter content and mineral distribution in peat soil is necessary. Lang *et al.*[3,4] systematically studied peat plant residues and the statistical classification of plant residue types as well as determined the microscopic characteristics of the components of the plant residues. Nie *et al.*[5] investigated the effect of the organic matter content and degree of decomposition in peat soil on the engineering properties in Northeast China. The results show that the higher the organic content in the peat soil, the higher porosity, moisture content, compressibility and internal cohesion will be. Inversely, with higher organic content, the lower will be the density, consolidation coefficient and permeability. Akira *et al.*[6] and Pitkanen *et al.*[7] adopted parameters, such as the decomposition rates of peat, oxygen consumption rates, rates of cellulolysis and biomass accumulation, to study the decomposition of peat soil, highlight the relationship between these parameters and the environmental factors of the research area and evaluate the effectiveness of these parameters. However, studies on the mineral distribution of peat soil at different depths are rare. In this article, a combination of X-ray powder diffraction and scanning electron microscopy is employed to study the mineral distribution at different depths of peat soil in northeast China, which could provide a solid foundation for mechanical property analysis and environmental impact assessment.

EXPERIMENTAL

With the use of the drilling method, test samples were obtained in a sampling area located in Dunhua city, Jilin province, northeast China, which is one of the densely distributed areas of peat soil. During indoor testing, the soil samples of the corresponding depths were unpacked. The undisturbed sample (100 cm^3) was removed with a ring knife and then washed over 0.1 mm soil sieve with distilled water to separate

the plant fiber and soil particles in the peat soil sample. The plant fiber was dried for the test of its decomposition rate (Table-2) and the filtrate was collected until the upper part was clear. The supernatant was then removed. The remaining soil samples were continuously dried for 48 h at 65 ºC and ground over 2 mm soil sieve until cooled to room temperature. The sample (5 g) was placed in a beaker (500 mL) and 25 mL of aqueous H_2O_2 solution (30 %) was added. The mixture was heated in a water bath at 80 ºC and stirred until the bubbles disappeared. The mixture was then vacuum-filtered and dried. Finally, the desferri process was performed using the method proposed by Mackenzie[8]. In order to collect the X-ray diffraction spectra, after drying, the peat soil samples have to be reduced and homogenized to powder form[9]. Therefore, all peat soil samples were ground by using a centrifugal mill to a 0.25 mm particle size and were sealed in sample bags for XRD using the SHIMADZU XRD-6000 X-ray diffractometer with the following conditions: Cu (λ = 1.5418 A), tube voltage of 40 kV, tube current of 40 mA and scan rate 4 °/min. The X-ray beam was partially diffracted and transmitted by the molecular layers in the sample[10]. Took the same depth of the peat soil for drying in the 65 ºC oven and then weighed 1-3 g dry soil for loss on ignition in the 550 ºC high temperature furnace (Table-2).

RESULTS AND DISCUSSION

The types of minerals at different depths in the peat soil do not substantially vary (Fig. 1). However, the diffraction peak intensity varies in each corresponding angle. In the qualitative analysis, the common parameter is d, which is converted from the angle of the XRD by Bragg's law ($n\lambda = 2d \sin\theta$)[11]. The XRD pattern of the different depths of peat soil is shown in Fig. 1.

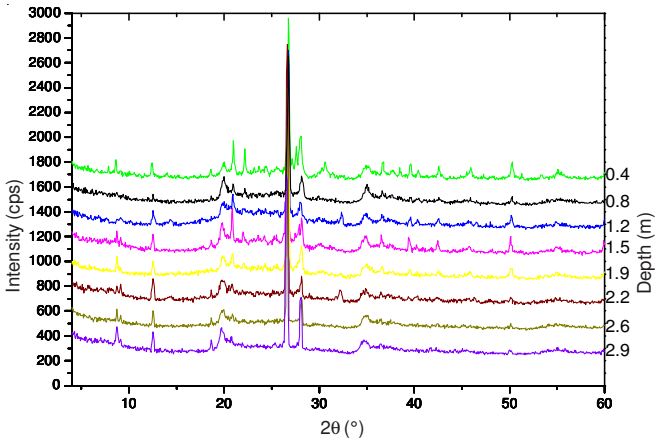

Fig. 1. X-Ray powder diffraction pattern at different depth of peat soil

Cook's method was used in this study to calculate the weight fraction of the minerals due to the fact that the results of Cook's law are relatively stable because fewer factors in this law are influenced by human[12]:

$$W_i\ (\%) = \frac{1}{\sum_{i=1}^{n} K_i I_i} K_i I_i \times 100 \quad (1)$$

where W_i = the mineral weight fraction of peat soil in the sample. K_i = a constant (intensity factor) which is dependent on instrument geometry, the peak intensities of the mineral being analyzed and the internal diffraction standard. I_i = the intensity of a given peak belonging to the mineral being analyzed. The results are shown in Table-1.

TABLE-1
MINERALS AND THEIR WEIGHT FRACTION OF PEAT SOIL AT DIFFERENT DEPTHS

Depth of peat soil (m)	Mineral weight fraction W_i (%)					
	Illite	Chlorite	Kaolinite	Quartz	Plagioclase	Mica
0.4	17	13	8	25	21	16
0.8	15	14	7	28	18	18
1.2	13	14	9	32	12	20
1.5	17	14	8	26	16	19
1.9	18	13	8	28	16	17
2.2	13	13	9	33	12	20
2.6	16	13	8	30	15	18
2.9	18	13	8	23	22	16

Table-1 demonstrates the slight differences in the types of minerals at a peat soil sampling site at different depths and their different weight fraction. The sample contains a small amount of clay minerals: illite, chlorite and kaolinite. Biscaye[13] reported that chlorite and illite have weak weathering intensities, indicating that the particles in the peat soil have weak weathering state before and after deposition.

Fig. 2 showed the mineral variation with different depth.

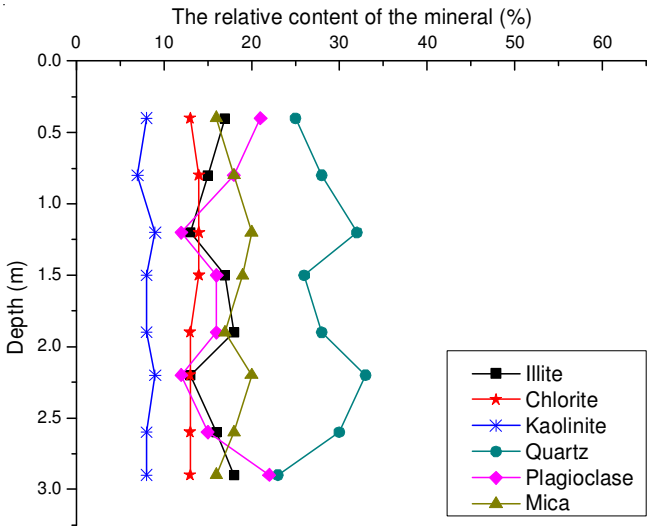

Fig. 2. Mineral variation with different depths

Quartz exhibits the maximum weight fraction with increasing depth, such that are significantly increased at 1.2 and 2.2 m deep. Fig. 1 demonstrates that the diffraction peaks of the two peat soil samples at 1.2 and 2.2 m deep are abnormal, using SEM (Fig. 3). Fig. 3(b-c) show a tiny, but abundant, root flocculent structure in these layers. Table-2 also demonstrates that the decomposition rate of peat soil at different depths changes, of which, the depths 1.2 and 2.2 m have much lower rate, meaning that there are more plant fibers providing a chemically adsorbed platform. Therefore, quartz (SiO_2) can largely cement in this structure because of its strong adsorption with the plant fibers[14]. Quartz is an associated mineral of mica, mica and quartz follow similar distribution trends.

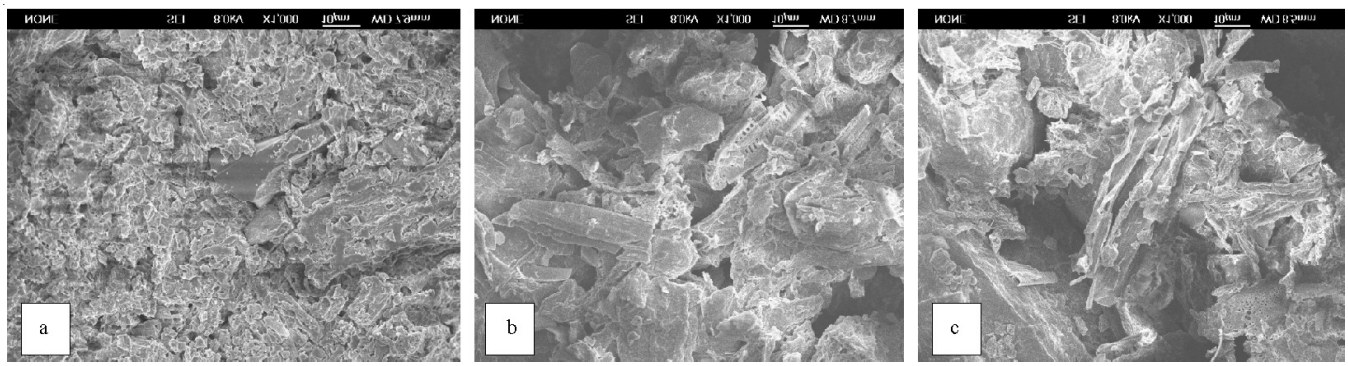

Fig. 3. SEM image of peat soil at the depth of 0.4 m, as a control diagram (a), SEM image at the depth of 1.2 m (b), SEM image at the depth of 2.2 m (c)

TABLE-2
LOSS ON IGNITION AND DECOMPOSITION RATE OF PEAT SOIL AT DIFFERENT DEPTHS

d (m)	0.4	0.8	1.2	1.5	1.9	2.2	2.6	2.9
L (%)	18.04	36.47	74.23	64.56	73.91	75.25	43.77	53.36
F (%)	73.1	48.3	40.4	43.5	50.3	36.8	42.4	70.5

F: Decomposition rate of peat soil. L: Loss on ignition of peat soil.

Illite evidently decreases at the two depth layers, by using software analysis, the ratio (A:B:C) of the hole area is 1:9.4:5.4 for depths 0.4 , 1.2 and 2.2 m, showing that the peat soil at 1.2 and 2.2 m deep has large porosity compared with the first layer of the peat soil. In addition, the major cation in illite contains Si, Al and K. However, the ignition loss tests of the peat soil showed that organic matter content is abundant at 1.2 and 2.2 m deep with values of 74.23 and 75.25 %, respectively, compared with that at 0.4 m with 18.04 %. The organic matter in the peat soil mainly consists of humic acid. The humic acid molecules contain a variety of functional groups, mainly oxygen-containing acidic functional groups, which include the phenolic hydroxyl group in the aromatic ring and carboxyl groups with aromatic and aliphatic compounds. Typically, these compounds have alkali metal ions (K^+), forming a stable ionic bond that easily runs off in the peculiar and subtle rhizomes with tubular structure in the peat soil, which would promotes the transformation of illite to kaolinite. The increasing kaolinite content due to the fact that the major cation in kaolinite contains Si and Al. In addition, the whole of illite along the hydraulic channel exhibits some losses, thus, the illite content is reduced accordingly.

Conclusion

Peat soil contains a small amount of clay minerals, of which illite is significantly reduced at 1.2 and 2.2 m deep because of the special structure and the abundance of humic acid in peat soil. The loss of K^+ in illite promotes the transformation of illite to kaolinite, increasing kaolinite content. Chlorite almost has no change along the depth but the presence of illite and chlorite shows that peat soil has a weak weathering state before and after deposition. Moreover, Peat soil contains a large amount of gravel soil minerals. Quartz is relatively the most abundant mineral in peat soil. Quartz is associated with mica, these two minerals present a similar trend that is significantly increased at 1.2 and 2.2 m depth on account of the tiny, but abundant, root flocculent structure. Plagioclase has a similar variation with and illite, as influenced by hydraulic channels.

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